DIESEL FUEL QUALITY EFFECT
STATUS REPORT

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by

Dr. N. Ostrouchov
Transportation Systems Division
Industrial Programs Branch
Conservation and Protection
Environment Canada

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Industrial Programs Branch
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Environment Canada
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SUMMARY

This report reviews the published literature concerning fuel effect on diesel particulate emissions. The effects and the costs of reducing particulate emissions by means of changes in diesel fuel composition are represented. Two specific changes were considered: a drastic reduction in diesel fuel sulphur content, and/or a moderate reduction in the aromatic hydrocarbon content. Canadian activities currently underway are discussed.

RÉSUMÉ

Ce rapport passe en revue la littérature publié sur l'effet du carburant diesel sur les emissions de particules provenant des moteurs diesels. Les effets et les coûts de réduire les émissions de particules en changeant la composition du carburant diesel sont présentés. Deux changements en particulier ont été considérés: une grande réduction du taux de soufre dans le carburant diesel et/ou une réduction modérée dans la teneur en hydrocarbures aromatisés. Les activités canadiennes dans ce domaine sont discutées.

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1 INTRODUCTION

Concern over the contribution of diesel engine particulate emissions to the environment has led the U.S. Environmental Protection Agency (EPA), the California Air Resources Board (CARB), and Transport Canada (TC) to include standards limiting particulate emissions from diesel powered vehicles in their new and proposed vehicle emissions regulations.

In Canada the federal limit for 1988 model year light-duty diesel passenger vehicle particulate emissions is 0.12 g/km and 0.16 g/km for light-duty diesel trucks, while heavy-duty diesel engines must meet a 0.22 g/MJ standard for 1988. The proposals for even stricter standards for heavy-duty trucks are a 0.093 g/MJ standard for 1991 (for urban buses 0.037 g/MJ), and a 0.037 g/MJ standard for all 1994 model year heavy-duty diesel engines. While there should be few technical problems with either light or heavy-duty vehicles meeting the 1988 standards, when combined with stringent standard for NOx emissions, the 1991 and 1994 levels could be difficult to achieve.

In attempting to meet such low particulate levels, the properties of the diesel fuel being used becomes quite important. Although numerous studies of fuel effects on diesel emissions have been reported in the literature, recently a series of test programs and engineering evaluations have been initiated in Canada and the U.S. to obtain more pertinent data on the effect of the diesel fuel properties on the emissions related to the proposed new standards.

This report summarizes and comments on the most important of the latest developments regarding diesel fuel quality effects.

2 U.S. EPA REPORT (EPA Contract No. 68-01-6543)

On March 15, 1986, the U.S. EPA proposed particulate emissions standards for heavy-duty trucks and buses for 1988, 1991, and 1994 model years. In their investigations leading to these regulations, EPA suggested regulating diesel fuel sulphur content because of its effect on particulate formations and commissioned a study "Diesel Fuel Quality Effects on Emissions, Durability, and Performance".(1) The results of that study basically state that reductions of sulphur and aromatics in diesel fuel will reduce particulate and SO_2 emissions from diesel engines, and the reductions can be achieved at little cost. The major conclusions of the study are as follows:

1. Reducing diesel fuel sulphur would reduce SO_2 emissions and the sulphate fraction of diesel particulates which would lead to a reduction of ambient levels of sulphate particles. In the U.S.A. the sulphur content of diesel fuel could be reduced from the present average of 0.274 percent to 0.048 percent by weight, without reducing the availability of diesel fuel. That is it would require no more than the present capital stock of fuel. The increase in average refining cost due to desulphurization was estimated to be 1.2¢ per U.S. gallon.
2. Reducing diesel fuel aromatics content would reduce the carbonaceous fraction of diesel particulate emissions. The average aromatics content of the fuel would also be reduced by desulphurization from the present 28.7 percent to about 20.3 percent by volume. The lower aromatics content due to desulphurization would also improve cetane numbers and ignition quality plus reduce cold starting problems and noise. It should be feasible to reduce the aromatic content to 17 percent by volume using the present capital stock. This would increase refining costs by about 0.4¢ per U.S. gallon beyond the cost of desulphurization. The incremental cost of particulate control by this means would be about $5.50 to $10.00 U.S. per pound of particulate matter eliminated.
3. Reducing the sulphur content of diesel fuel would significantly reduce corrosive wear and deposit formation, extending engine life and reducing maintenance costs. A conservative estimate based on the limited data available indicated that these savings would be about four times the increase in refining costs.
4. Contrary to common belief, changes in the distillation temperatures (such as the 90 percent point and end point) have little potential for emission control.

Comments:

Many of the estimated effects shown in the report are based on incomplete data, different test methods and different engines tested. Therefore the effects noted are only valid in establishing the direction and approximate magnitude of the effects of fuel sulphur and aromatics content as well as 90 percent distillation point on particulate emissions. Actual refinery processes and crude oil composition vary, so that the reduction in average aromatics due to the sulphur limit would not be seen in every case.

3 GENERAL MOTORS REPORT (December 22, 1986)

On May 13, 1986, EPA requested a meeting with General Motors to continue EPA's assessment of the overall status of the GM trap-oxidizer development for HD engine application. The meeting was held on August 14, 1986 and included presentations on the efforts and status of the HD diesel engine particulate controls being developed by GM.

It was established by EPA that additional information from diesel engine manufacturers was needed to provide supporting data to initiate rulemaking to remove sulphur from diesel fuel. To obtain this information, specific short term research projects on HD engines were initiated by EPA. The principal issue addressed was the impact of diesel fuel sulphur level on the ability to meet the 1991 and subsequent model year HD diesel engine particulate emission standards in the U.S.A.

During its particulate control development program, Detroit Diesel Allison (DDA) has run transient particulate emission tests on some of its engines with commercially available diesel fuels that varied not only in their fuel sulphur level, but also in their aromatic content and to some extent in their 90 percent boiling points.(2)

The following results were obtained from the test program; the series 60 and 8.2 L heavy-duty diesel engines were tested: (Please note that some information in the GM report was labelled as confidential and therefore is not disclosed in this report.)

1. Fuel Sulphur Effects on Particulate Emissions. The test data obtained on the transient test procedure show an average reduction of 0.029 g/MJ of particulate as the fuel sulphur level is changed from 0.30 percent to 0.06 percent along with an unspecified reduction in aromatics (averaged data), Table 1.

2. Effect on Engine Technology Level on Sulphate Conversion. The improvements in technology include electronic engine control and air charge cooling. GM found that

TABLE 1 EFFECT OF FUEL MODIFICATIONS ON DIESEL DERIVED ATMOSPHERIC PARTICULATE

Fuel Composition			Particulate Emissions, g/MJ							
			Directly Emitted							
S,Wt %	A,Vol %	T_{90} °C	Carbon	Sulphate	Secondary Sulphate	Total Directly Emitted	Total Directly Plus Second Emitted	Reduction of Directly Emitted %	Reduction of Directly Plus Second Emitted %	Reference
0.50	32	316	0.076	0.067	1.010	0.143	1.153	0	0	
0.25	32	316	0.076	0.034	0.505	0.109	0.614	24	47	
0.05	32	316	0.076	0.006	0.101	0.082	0.183	43	84	
0.05	10	316	0.055	0.006	0.101	0.061	0.162	57	86	
0.05	10	260	0.044	0.006	0.101	0.050	0.151	65	87	11 - CHEVRON
0.34	30	318	0.065	0.017	N/A	0.082	N/A	0	N/A	
0.138	21	338	0.050	0.015	N/A	0.065	N/A	21	N/A	
0.30	N/A	N/A	N/A	N/A	N/A	0.117	N/A	0	N/A	9 - CARTELLIERI
0.06	N/A	N/A	N/A	N/A	N/A	0.088	N/A	25	N/A	
0.60	N/A	N/A	N/A	N/A	N/A	0.153	N/A	0	N/A	
0.32	30.6	324	N/A	N/A	N/A	0.112	N/A	27	N/A	
0.04	12.5	332	N/A	N/A	N/A	0.074	N/A	52	N/A	2 - GM
0.84	N/A	324	0.807	0.056	N/A	0.863	N/A	0	N/A	
0.71	N/A	330	0.756	0.036	N/A	0.792	N/A	8	N/A	
0.67	N/A	324	0.547	0.033	N/A	0.580	N/A	33	N/A	
0.35	32.1	314	0.229	0.015	N/A	0.244	N/A	72	N/A	
0.01	10.6	329	0.159	0.001	N/A	0.160	N/A	81	N/A	3 - MACK TRUCKS
										10 - ULLMAN

N/A = Not Available

fuel sulphur to sulphate conversion efficiencies on various DDA particulate control development engines, tested at fuel sulphur levels varying from 0.28 to 0.36 percent, were not reduced with improved engine technology.

3. Effect of Fuel Sulphur Level on Engine Wear. The test results indicate that as the fuel sulphur level is changed from 0.06 percent to 0.26 percent, an increase of three to four times in top ring wear is observed. The trend is considered to be highly reliable.

4. Possibility of Meeting 1991 Particulate Standards with Low Sulphur Fuel. The test data indicate that reducing the fuel sulphur level to 0.05 percent will greatly improve the probability (the deterioration factors and variability between engines are not known at present) of meeting the 1991 particulate emission standards without requiring any trap-oxidizer type aftertreatment devices. Low sulphur fuel is also expected to help in reducing deterioration factors as the result of decreased engine wear. The application of technologies demonstrated on the series 60 and 8.2 L engines, as well as the availability of low sulphur fuel, could improve the probability of meeting 1991 emission standards for other DDA produced HD diesel engines as well.

5. Trap-Oxidizer versus Fuel Sulphur Removal Life Cycle Costs. Assuming that the 1991 emission standards can be met with low sulphur fuel, the trade off between costs of low sulphur fuel and trap installation to meet 1991 particulate standards heavily favours fuel sulphur removal. According to GM, the cost of sulphur removal will have to exceed 3.7¢/L to make the diesel fuel sulphur removal option less desirable.

6. Fuel Sulphur Effects on Catalytic Converter Development. Most of the catalysts examined, which are active in decreasing HC and particulates, also convert SO_2 to sulphates and/or sulphuric aerosols, in some cases to such a large extent, that converter-out particulate levels are higher than converter-in particulate levels. In addition, the sulphates and/or sulphuric aerosols may react with the alumina support in the catalyst. Sulphur and sulphur compounds will also reduce the catalyst's activity. However, if low sulphur fuel is available by 1991, it might be possible to develop a catalytic converter type particulate control system which will be more efficient, more durable and less expensive when compared to a trap-oxidizer (forced

regeneration) type system. The developments in control technology will be discussed in a separate status report.

7. Air Quality Impact. Even though mobile source SO_2 emissions are only a relatively small portion of the overall ambient SO_2 problem, diesel emissions are the largest contribution to the mobile source particulate sulphate inventory. The HD diesel fuelled vehicle has an SO_2 emission rate equivalent to an emission rate of 3.31 g/mile at a fuel sulphur level of 0.25 percent by weight and 0.66 g/mile at a fuel sulphur level of 0.05 percent.

Comments:

The GM data are obtained from the standard U.S. EPA transient test procedure, and are comparable to the HD vehicle particulate emission standards. However, the data do not separate experimentally the effect of sulphur content, aromatics content and 90 percent distillation point. Therefore the need for specially designed experiments and fuels to separate the fuel sulphur effects from the other fuel variables is necessary.

4 MACK TRUCKS REPORT (February 27, 1987)

Mack Trucks has also conducted a brief study of the effect of fuel sulphur content on their largest selling engine (not specified).[3] They determined that at approximately a level of 1.860 g/MJ NO_2 each 0.1 percent reduction in fuel sulphur content produced 0.014 g/MJ reduction in particulate emission. This finding indicates that for a reduction in fuel sulphur from 0.3 percent to 0.05 percent, particulate emissions will be reduced by approximately 35 percent.

Comments:

The test results on the effect of fuel sulphur content on particulate emissions from HD diesel engines obtained by Mack Trucks are practically the same as obtained by GM, Figure 1. The report, however, indicates that low sulphur content fuel (0.04 percent kg wt.) tested had substantially lower aromatics content (12 to 13 percent) if compared to the standard D-2 fuel aromatics content (30.6 percent). The lower aromatics content could by itself reduce particulate emissions substantially.

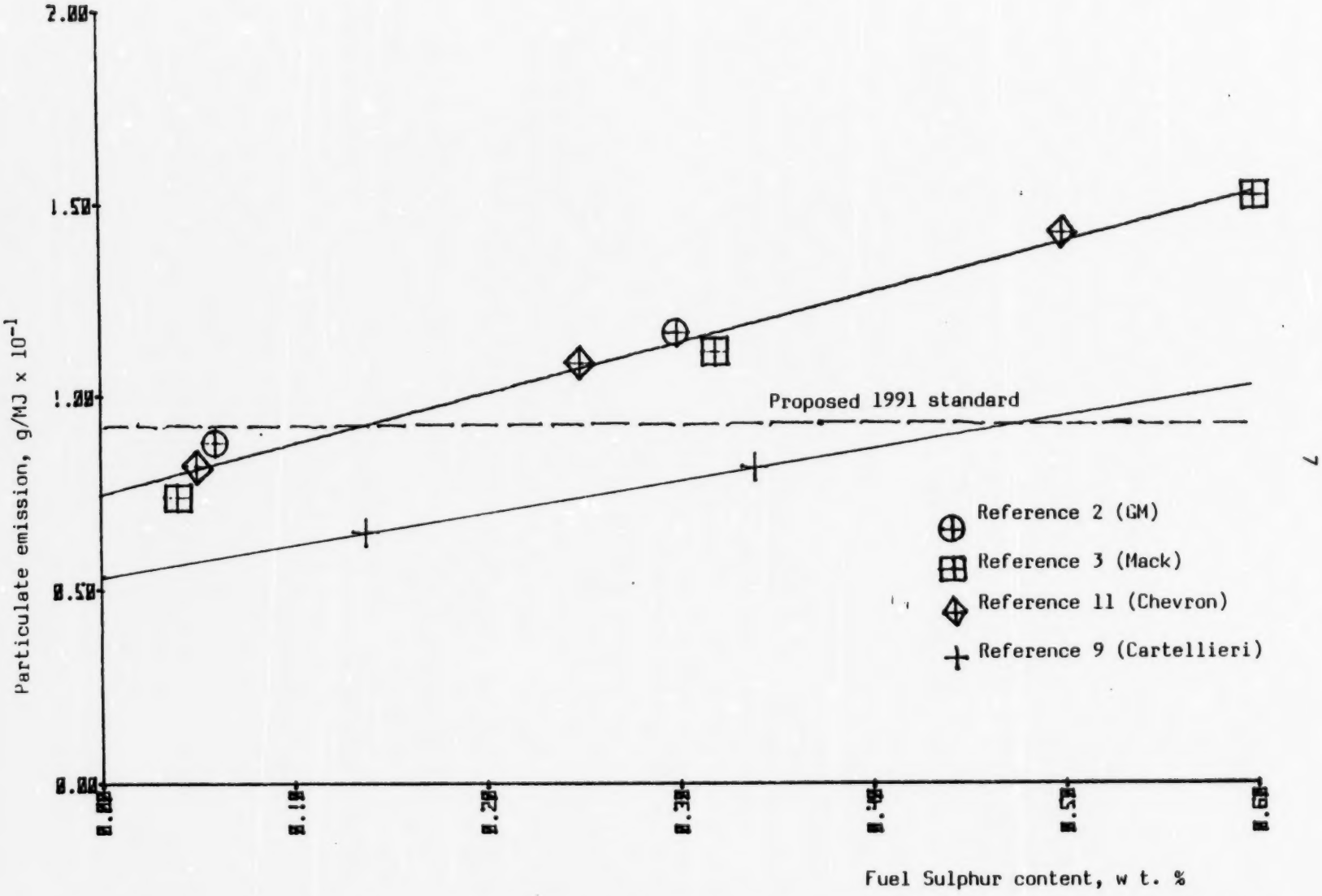

FIGURE 1 EFFECT OF FUEL SULPHUR CONTENT ON DIESEL DERIVED DIRECTLY EMITTED PARTICULATES

5 OTHER STUDIES

5.1 **Berry** et al. (12), 1985, found that the magnitude of the increase in mass particulate emissions with increasing fuel sulphur content was about 5 percent per 0.1 percent change in fuel sulphur content. They also found that the combination of sulphate and bound water contributes 0.028 and 0.082 g/MJ to the total particulate mass at the low (0.20 percent) and high (0.55 percent) sulphur levels, respectively. Thus at the current Canadian average fuel sulphur level of about 0.25 percent to 0.30 percent, about 0.037 g/MJ of sulphates and bound water would be collected as particulate. This is 40 percent of the proposed 1991 particulate standard, and 100 percent of the 1994 standard.

Comments:

The data in this study were obtained using steady-state and not standard U.S. EPA transient test procedure prescribed for HD engines. The report found that the magnitude of the increase in mass particulate emissions with increasing fuel sulphur content was about 5 percent per 0.1 percent change in fuel sulphur content, or that increasing fuel sulphur content by 0.24 percent (from 0.06 percent to 0.30 percent) will contribute 2.4 x 5 = 12 percent to the total particulate mass. The GM study, which is based on the U.S. EPA transient test procedure, however, shows that the same increase in fuel sulphur content will increase the total particulate mass by 25 percent or twice as much, Table 1.

5.2 **Khatri** et al. (2), 1986, found that a fuel containing 0.3 percent sulphur would contribute between 0.008 and 0.037 g/MJ of sulphate emissions including bound water over a wide range of engines.

Comments:

The data in this study were obtained using steady-state and not standard U.S. EPA transient test procedure. The results of sulphate contribution to the directly emitted particulate mass reported by other researchers are comparable to the range found by Khatri for the same fuel sulphur content, Table 1.

5.3 Chevron (11), 1987.

The most extensive recent study on the effect of diesel fuel quality was made by Chevron Research Company in California[11], 1987. However, because these estimates are based on California refiner's data, they may not be representative of refiners elsewhere in U.S.A. and in Canada. Nonetheless, the general analysis is applicable to other refiners.

The study found, that atmospheric particulate from diesel engines results from the direct emission of exhaust particulate, and from the formation in the atmosphere of secondary particulate from gaseous exhaust emissions, Table 1. Direct emitted particulate is composed of carbonaceous material (here defined as the carbon-containing nonextractable material plus the carbon-containing extractable material, often called the soluble organic fraction), sulphuric acid, and bound water. Secondary particulate can be formed by reaction of the gaseous SO_2 from the exhaust with oxygen, ammonia, and water in the atmosphere to form ammonium sulphate particulate.

Table 1 shows the particulate emissions data for each fuel reported in reference 11, broken down into directly emitted carbonaceous particulate, directly emitted sulphate, and secondary sulphate (assuming a 50 percent rate of conversion of SO_2 to sulphate in the atmosphere). The particulate emissions were calculated using a cycle-averaged brake specific particulate emissions from the most extensive database published to date[11], and from the engines representative of the manufacturers who supply the majority of the heavy-duty truck market (Cummins and Caterpillar).

The data in Table 1 clearly show the large contribution of primary and secondary sulphates to total particulate emissions. As can be seen from the table reducing only sulphur content, maximum 0.50 percent in current Canadian diesel fuel, to 0.05 percent is estimated to reduce directly emitted particulate emissions by 43 percent and the combined directly emitted plus secondary particulate emissions by 84 percent. Reduction of aromatics from 32 percent to 10 percent reduced directly emitted particulates by about 25 percent, and reduction of the 90 percent point from 316°C to 260°C reduced directly emitted particulate emissions by an additional 18 percent. While this calculation was not derived from transient data (13-mode cycle was used), the study states that the bulk of the distance accumulated on over-the-road trucks occurs at essentially steady-state conditions.

The study also estimated the processing cost for fuel modifications. Table 2 shows individual California refiners estimated processing costs for the fuel modification scenarios. The costs are given as incremental costs above the normal cost to produce the

TABLE 2 ESTIMATED INCREMENTAL COST TO MODIFY DIESEL FUEL FROM BASE SPECIFICATION: (Reference 11)
Sulphur = 0.23 %, Aromatics = 33 %, 90 % Point = 322°C (in U.S. cents/litre)

		Modified Fuel		
		1	2	3
Maximum sulphur content, Wt. %		0.05	0.05	0.05
Maximum aromatics content, vol. %		33	10	10
Maximum 90 % distillation temp., °C		322	316	260
		Cost increment (¢/L)		
Company Identification	A	0.82	9.82	10.05
	B	0	4.35	9.86
	C	1.74	2.61	3.89
	D	0	4.84	9.47
	E	0.13	3.19	5.43
	F	0.48	1.66	6.01
	G	1.76	3.75	6.74
	H	2.50	5.13	5.13
	I	2.10	-	-
	J	0.13	5.98	-
	K	0	4.17	8.35
Weighted Average by Market Share		0.69	4.18	7.31

base fuel. The study assumed that only 43 percent of No. 2 distillate pool would need to be desulphurized.

Comments:

The test results in the above study were obtained using the steady-state test procedure and therefore theoretically are not comparable to the standard U.S. EPA transient test cycle. However, in practice the results are exactly the same as GM results obtained from U.S. EPA transient cycle, Table 1 and Figure 1.

Although the amount of sulphates formed under various conditions has been measured quite extensively, the mechanism by which the sulphates are formed

particularly in the atmosphere (secondary sulphates) is not completely clear. In addition, catalytic surfaces almost certainly play an important role, as do competing reactions of NO_x in the secondary sulphate formation. It should be noted, however, that it is likely that under ambient conditions all of the SO_2 formed during combustion eventually is oxidized to some form of sulphates. In considering diesel particulates and particulate standards, however, it is the fraction of SO_2 converted to sulphate in either the engine or the exhaust system that is important and that is the fraction which should be considered when discussing emissions standards.

The study does not indicate what will be the effect of reducing aromatics and/or 90 percent point temperature on diesel fuel consumption, maximum power, startability and drivability.

5.4 **P. Cartellieri** et al.[9], 1987, tested a direct injection 4-stroke, 6 cylinder diesel engine with displacement of 11.5 litres, using modified transient EPA test cycle. According to the study, reducing fuel sulphur content from 0.34 wt. percent to 0.138 wt. percent will reduce total directly emitted particulate emissions by 21 percent (from 0.082 g/MJ to 0.065 g/MJ). It should be noted that the engine was extensively modified to obtain the above results.

Comments:

This study uses a modified U.S. EPA test procedure which is not necessarily comparable to the standard U.S. EPA transient test cycle. The effect of sulphur-content on directly emitted particulate emissions found by Cartellieri is plotted in Figure 1. However, as can be seen from the figure, Cartellieri obtained excellent results in lowering particulate emissions by engine modification alone.

5.5 **T. Ullman** et al.[10], 1987, tested an International Harvester Model DT-466B heavy-duty diesel engine using three crude and two minimally processed shale oils. Hot-start EPA transient test cycle was used for testing. Table 1 shows the substantial reduction of directly emitted particulate which accompanied the reduction of fuel sulphur content obtained from these tests.

Comments:

The study uses hot-start U.S. EPA transient test procedure instead of cold-start test. This was necessary, since cold-start transient operation on the crude shale oil was impractical because of high viscosity of the oil. Substantially different properties of crude shale oils if compared to standard diesel oils do not allow comparison of the absolute levels of particulate emissions between these two fuels. However, the test results clearly show the large contribution of fuel sulphur content to total particulate emissions, Table 1.

6 AMERICAN PETROLEUM INSTITUTE REPORT (March 31, 1987)

The American Petroleum Institute (API) review of the EPA report on Diesel Fuel Quality Effects on Emissions, Durability and Performance makes a claim that the EPA report "...underestimates the costs of reducing the sulphur, and aromatics content of diesel fuel and exaggerates the benefits of doing so."(4)

The API report stated, that the EPA study did not accurately reflect either current U.S. diesel fuel demand performance requirements or refining capacity and technology. In addition, it is claimed that the EPA report inappropriately analyzed published data on the effects of diesel fuel sulphur and aromatic content on engine emissions, durability and performance.

Comments:

As I am not familiar with refining industry modelling, I cannot comment on this topic in API report. However, the following are my comments on topics related to diesel engines which are described in the API report:

1. The API report stated, that the effects fuel sulphur on engine wear is not the main reason for a decreased engine life, and listed many additional reasons related to engine overhauls in addition to piston ring wear. However, fuel sulphur effect on increased wear of engine piston rings and cylinder walls is still considered by most experts the main reason for decreased engine life from engineering point of view. I feel that both API and Energy and Resource Consultants (ERC) incorrectly analyzed published data on the magnitude of diesel fuel sulphur effect on piston ring wear. In both cases their data underestimates wear since the tests were conducted at a fixed-speed, high load operating conditions on a diesel locomotive engine. The

driving cycle of the locomotive engine is quite different (mostly fixed-speed and high load) from a diesel truck engine (changing speed and normally under medium to low load). Because the effect of sulphur content will increase with lower engine load (lower cylinder temperature and increase in cylinder condensation and formation of sulphuric acid), wear to piston rings and cylinder walls will be higher in diesel truck engines. Cold climate may make sulphur induced wear more severe in Canada.

2. The API report states, that reducing aromatics from the current average of 29 vol. percent to 20 vol. percent would decrease fuel economy and maximum power by 1.5 to 2.0 percent, because it would result in a 3 percent to 4 percent reduction in the net heating value of diesel fuel. The API also estimated that a fuel sulphur reduction from 0.276 percent to 0.05 percent could increase the specific gravity of diesel fuel by about 2 API degrees and, as a result, increase fuel consumption by about 0.6 % and decrease maximum power by a similar amount. However, the API fails to mention that the increased cetane number of diesel fuel resulting from a lower aromatic content may compensate for these losses.
3. The API listed many sources which indicate that the sulphur content in particulate emissions is substantially lower than presented in the EPA report. However, none of the sources listed used a transient test cycle for particulate emission measurements as was the case for the GM tests.
4. The API report also did not refer to the reduced acid loading in the engine oil if diesel fuel sulphur content is reduced. Such a reduction might extend oil change intervals, reduce the overall cost of lub oil, and reduce the alkaline ash content of the oil which would help to extend trap-oxidizer life.

7 CURRENT RESEARCH

U.S.A.

To define a common area of concern in the emission control impacts on diesel fuel composition, the U.S. EPA initiated a program mounted by U.S. Coordinating Research Council (CRC).[5] The CRC program VE-1 is designed to test 7 basic and 2 low (now 0.05 percent) sulphur and different aromatic diesel fuels on 4 HD diesel engines to EPA transient test cycle requirements and record the emission compounds with particulate and benzene emissions. The fuels used in the test program are designed to

specifically address the fuel variables being considered by EPA for possible regulation, aromatics, volatility, and fuel sulphur.

Results for the first test engine should be available by the second quarter of 1987, and results from each additional engine about every four months.

CANADA

The need and cost of any changes in diesel fuel quality to operate successfully with any new engine and other emission control technology are of concern not only in the U.S.A. but also in Canada, particularly to the Canadian petroleum industry who will be required to supply fuel compatible with any new engine technology. It is particularly important that Canada keep pace with developments in the U.S.A. since all heavy-duty diesel engines are manufactured in that country or abroad.

Esso contacted EMR[6] about the need for research program to resolve some of the uncertainties. The Ontario Research Foundation (ORF) was selected by EMR to perform a diesel fuel quality research contract.[7] This contract results from prior approaches from industry to EMR to consolidate R&D in this area on a 50/50 Industry/Government basis. The object of the program will be to provide information on the range of anticipated diesel fuel composition combinations in the post-1994 environment and on the emissions resulting from the use of those fuels. Additional information on low temperature effects and particulate trap performance will be included in the program to provide input to government considerations for emissions legislation.

The U.S. CRC has encouraged Canadian involvement in a fuel quality effect program, since there will be in Canadian fuel a different range and type of aromatics present due to the use of synthetic crudes from the tar sands and because the CGSB diesel fuel specification allows a 90 percent point up to 360°C as compared to only 340°C by the ASTM specification in the U.S.A.

All engine manufacturers have supported the CRC and EMR programs, and have indicated their interest to cooperate with the supply of appropriate engines. Engine manufacturers are therefore willing to ship all four test engines being used on the CRC programs to ORF for tests with Canadian diesel fuels. All four diesel engines contain engine technology that will allow them to meet the 1988 emission standards.

It should be noted, however, that ORF will use a modified EPA heavy-duty transient emission test procedure.[13] In order to assess the emission implication of a modified test procedure, a heavy-duty diesel engine, DDA Series 60, was tested both at

ORF and at the engine manufacturer's facility (the engine is the same type as tested by CRC). When the data from the modified cycle and the EPA cycle were compared it was found that the ORF emission results fall within 5 percent of the full EPA cycle. This interlab comparison is considered by the Engine Manufacturers Association (EMA) to show better correlation than is generally obtained in round robin testing between various engine manufacturers (10 percent). Engine manufacturers are therefore willing to accept the ORF results as comparative data to the EPA certification procedure. It was suggested during discussion, that one test fuel should be the CRC Reference Fuel for future correlation purposes.

The time schedule for the program is as follows:[7]

1. Phase II, Emissions Characterization – June 1988
2. Phase III, Cold-Start Emissions Testing – August 1988
3. Phase IV, Trap Technology Evaluation – 1988/89.

During the panel discussion of test schedule the "ideal" time of delivery of test results for the timing of regulatory findings was given as September 1987, for 1991 regulatory consideration.

8 DISCUSSION

Very little information exists in the literature on the effects of diesel fuel composition on either gaseous or particulate emissions, primarily because of the lack of investigations of sulphur, aromatics, and 90 percent distillation point as an independent fuel variables. In addition the sensitivities of emissions to fuel composition observed in available studies were derived from steady-state, modified U.S. EPA transient testing and standard U.S. EPA transient testing making comparison very difficult.

In Figure 1 an attempt was made to compare the effect of fuel sulphur content on particulate emissions, derived from four independent studies.[2,3,9,11] The comparison indicates that reducing fuel sulphur content below 0.10 wt. percent may reduce directly emitted particulates mass below proposed 1991 standard without aftertreatment technology.[2,3,11] The data also indicates, however, that extensive engine modification[9] may reduce particulate emissions below 1991 standards without reducing fuel sulphur content and without using an aftertreatment technology. However, caution should be exercised in interpreting the data, because as mentioned before, different test procedures and different or unknown fuel aromatics contents were used by different

researchers. The U.S. EPA initiated within the CRC the VE-1 program which will quantify the effects of fuel changes on the most modern heavy-duty technology diesel engines. Canada will keep pace with developments in the U.S.A. and EMR has contracted The Ontario Research Foundation to introduce its own program to provide information on a range of anticipated diesel fuel composition mixtures using the same engines tested by the CRC.

9 REFERENCES

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2. General Motors Comments on EPA Notice Federal Register Volume 51, No. 124, June 27, 1986. Diesel Fuel Quality Effects on Emissions, Durability, Performance and Costs, December 22, 1986.

3. Mack Trucks letter to Mr. A.K. Hazra, Transportation Systems Division, March 10, 1987.

4. Comments from the American Petroleum Institute in response to EPA's Federal Register Request for comments on Diesel Fuel Quality. Report submitted by PACE as an attachment to the letter to Mr. A.K. Hazra, Transportation Systems Division, March 31, 1987.

5. G. Mound, EMR, Debriefing note: visit to CRC Atlanta and S.W. Research Institute (SWRI) 14 and 15 January 1987.

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